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THE MAGNETIC STATE OF $ErNi_2B_2C$ IN AN IN-PLANE FIELD

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We present a neutron-diffraction study of the magnetic structures of superconducting $ErNi_2B_2C$ in the presence of a magnetic field. At zero field, the magnetic structure is transversely polarized with $\boldsymbol{Q} = 0.55\boldsymbol{a}^*$ and the moments along the $\boldsymbol{b}$ direction. Transitions of $\boldsymbol{Q}$ between different commensurable values are observed when varying the field. The commensurable structures are analyzed in terms of a detailed mean-field model. Experimentally, the minority domain shows no hysteresis and stays stable up to a field close to the upper critical field of superconductivity, ($H \parallel [010]$). Close to the upper critical field of superconductivity ($H \parallel [110]$), we observe that $\boldsymbol{Q}$ rotates a small angle of about 0.5° away from the [100] direction.

In $ErNi_2B_2C$, the erbium ions are placed in a body-centered tetragonal lattice, with $a = b = 3.502$ Å^{-1} and $c = 10.558$ Å^{-1}. The Néel temperature is $T_N \approx 6$ K and the superconducting transition occurs at $T_c = 11$ K.[1] In this study, the magnetic structures of $ErNi_2B_2C$ are examined in general in the presence of a magnetic field, and specifically close to H_{c2}, in order to improve the understanding of the interdependence of superconductivity and magnetism.

A single crystal of approximate size $2\times3\times0.5$ mm^3 was prepared as described in Ref. 2. The neutron diffraction experiments were performed at BENSC using the E1 triple axes spectrometer and a 4 T horizontal cryomagnet for fields along [1 0 0] and [1 1 0]. The mean-field model includes crystal field parameters, RKKY-exchange, the classical dipole-dipole interaction, and a quadrupole coupling.[3] The crystal-field and quadrupole parameters have been established from neutron scattering and x-ray experiments. The exchange coupling has been derived from a fitting of the bulk magnetization[2,4] and neutron diffraction data[5].

At zero field, the magnetic domains with $\boldsymbol{Q} = \boldsymbol{Q}_A$ or $\boldsymbol{Q}_B$ are equally populated, but the application of the magnetic field along [010] suppresses the domain with the magnetic moments perpendicular to the magnetic field, i.e., the $\boldsymbol{Q}_B$ domain. The intensity of the minority domain is completely suppressed at 13 kOe, as shown in the lower left part of fig. 1. Surprisingly the minority domain shows no hysteresis. The minority domain was expected to be metastable in a field, and after being eliminated at some field, to be energetically unfavorable when decreasing the field. The critical field for the minority domain is close to the upper critical field of superconductivity, indicating that the existence of fluxlines might stabilise the minority domain. The ordering vector of the magnetic phase is $\boldsymbol{Q} = 11/20\boldsymbol{a}^*$ in zero field, and when applying a magnetic field $\boldsymbol{Q}$ increases in jumps to different commensurable structures. The period of the magnetic structure (for H || [010]) is presented in Fig. 1 and the dashed lines indicate the possible commensurable values of $\boldsymbol{Q}$. For both field directions, the period changes as follows: $\boldsymbol{Q}$ = 0.55 to $\boldsymbol{Q}$ = 0.57 to $\boldsymbol{Q}$ = 0.58 or 0.59 and back to $\boldsymbol{Q}$ = 0.57. An overview of the states is presented in figure 2, where the black dots mark the measured data points. For both field directions two-phase regions exist in the transition from one structure to another, however due to different resolutions, this can be resolved only in the [110] case, indicated by striped areas. A peculiarity is a small, but clearly detectable rotation of the ordering vector, which occurs close to and above the superconducting critical field for $H \parallel [110]$. This feature and the high field stability combined with a lack of hysteresis of the minority domain for $H \parallel [010]$, indicate possible connections to superconductivity, which cannot be confirmed in this study.

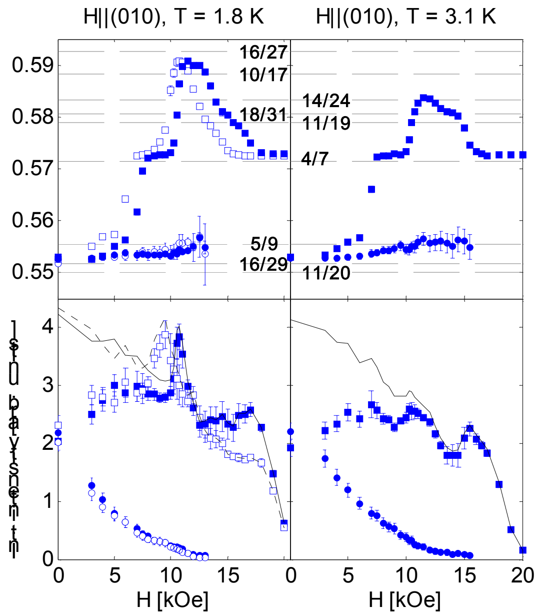

Fig. 1. Positions and integrated intensities of the majority domain measured at (200) – $\boldsymbol{Q}_A$ (squares) and of the minority domain (020) – $\boldsymbol{Q}_B$ (circles). The solid symbols represent the data obtained when increasing the field, and the open ones show the decreasing-field data. In the lower part of the figure, the sums of the magnetic intensities of the two domains are indicated by lines (solid: increasing field; dashed: decreasing field).

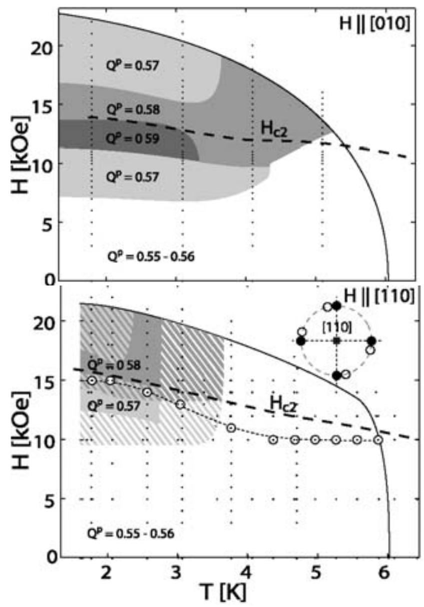

Fig. 2. Magnetic phase diagrams for fields applied along [010] and [110]. White and gray areas indicate single-phase regions, whereas striped areas represent two-phase regions. Bottom: A small orthogonal component $\delta\boldsymbol{Q} \approx -0.005\boldsymbol{b}^*$ appears above the dashed line with open circles. The insert shows the rotation of the magnetic reflections.

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